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Jumper's Knee or Lander's Knee? A Systematic Review of the Relation between Jump Biomechanics and Patellar Tendinopathy

Authors

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Key words

- sports
- soft tissue injuries
- leg injuries
- patellar tendon
- biomechanics

Abstract

Patellar tendinopathy (jumper's knee) is a common injury in sports that comprise jump actions. This article systematically reviews the literature examining the relation between patellar tendinopathy and take-off and landing kinematics in order to uncover risk factors and potential prevention strategies. A systematic search of the Pubmed, Embase and Amed databases was performed to identify studies that reported kinematics of sport specific jumps in relation to patellar tendinopathy. A quantitative analysis was performed on 4 identified studies. Differences were found only between controls and asymptomatic subjects with patellar tendon abnormalities.

Most differences were found during horizontal landing after forward acceleration. A synthesis of the literature suggests that horizontal landing poses the greatest threat for developing patellar tendinopathy. A stiff movement pattern with a small post-touchdown range of motion and short landing time is associated with the onset of patellar tendinopathy. Accordingly, employing a flexible landing pattern seems to be an expedient strategy for reducing the risk for (re-) developing patellar tendinopathy. Together, these findings indicate that improving kinetic chain functioning, performing eccentric exercises and changing landing patterns are potential tools for preventive and/or therapeutic purposes.

Introduction

Patellar tendinopathy (PT), also known as jumper's knee [3], is a common injury in sports that involve repetitive jumping, such as basketball and volleyball. In elite and recreational basketball players the prevalence is 32 and 12%, respectively, while in elite and recreational volleyball players it is 45 and 14%, respectively [17,35]. Prevention of this injury is important because symptoms can last for years, affect sports and work participation, and even be a reason to end a sports career [12,29]. Moreover, although several treatments have been described, treatment results are variable [10]. In order to develop preventive measures, knowledge of risk factors is necessary [8]. Many risk factors have been suggested in the literature, and it appears that PT has a multifactorial aetiology. Weight, body mass index, waist-to-hip ratio, leg-length difference, arch height of the foot, quadriceps flexibility, hamstring flexibility, quadriceps strength, vertical jump performance and training volume are thought to be risk factors for PT [28,30]. The high

prevalence of PT in sports involving jump actions suggests that PT is instigated through jumping, that is, by take-off and/or landing (and, hence, the label jumper's knee). Therefore, to understand the aetiology of PT, it is necessary to at least understand the relation between PT and take-off and landing. Indeed, a number of biomechanical studies have investigated how characteristics of take-off and landing may be related to PT. The aim of this systematic review is to come to a better understanding of how PT may be related to take-off and landing biomechanics. Studying both jump phases may give more insight into the development of PT, while also addressing the question whether take-off and landing potentially pose different risk for developing PT. In this way risk factors may be uncovered which can be used to identify take-off and/or landing patterns in athletes which predispose them for developing PT. Subsequently, potential means for prevention and rehabilitation of PT can be developed through changing these predisposing patterns.

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Bibliography

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Methods



Search strategy

A computerized search of the Pubmed, Embase and Amed databases was conducted in October 2012. The following terms were used: patella(r) tendon, jumpers knee, jumper's knee, patella(r) tendinopathy, patella(r) tendinosis, patella(r) tendinitis, patella(r) tendonitis, patella(r) apicitis, patella(r) apex syndrome, patella(r) tip syndrome, patella(r) tenosynovitis combined with jump, jumping, land, landing, take off, touchdown and plural forms. The search was restricted to articles in English. Abstracts, letters and reviews were excluded. Reference lists of the included studies as well as other relevant studies were checked for additional references. Studies were included if they met the following 3 criteria: 1) It was an empirical study that investigated jump and/or landing characteristics of sport specific jumps in relation to PT, 2) kinematics of these jumps were collected, and 3) a comparison was made in that study between a control group and a group with (a)symptomatic PT. Titles and abstracts were screened independently by 2 authors to determine inclusion or exclusion. If it was not clear whether the study should be included, the full-text was screened.

Data on study population, jump tasks and kinematics were extracted from the included studies. If some data was not available in the article, the authors were contacted by email for additional data.

Methodological assessment

The methodological quality of the included studies was rated by 2 authors (HW, IA) with a methodological quality checklist that was developed by Downs & Black (1998) for assessing both randomized and non-randomized studies. The checklist has been used before to study the relation between biomechanics and sports injury [20]. The 13 items of this checklist that were considered relevant for cohort and case-control studies were scored by the 2 authors. Any differences in quality assessment between the 2 reviewers were resolved through consensus.

Statistical analysis

A quantitative analysis was performed on the kinematic variables of the identified studies. Effect sizes (Cohen's *d* with 95% Confidence interval (CI)) were calculated from means and standard deviations to compare study results. Means and standard deviations of the kinematic variables were extracted from the articles or, if not presented in the article, obtained from the authors. If the 95% CI of the effect size did not cross zero the variable was considered to be significantly different between groups. A positive Cohen's *d* reflected a greater value in cases compared to controls. Because of the small sample sizes in the studies, 90% CIs for the effect sizes were also calculated. Factors with a 90% CI that did not cross zero were considered to be "showing a trend towards significance". Forrest plots of the effect sizes were created for visual comparison for all kinematic variables of each study.

Results



The search of electronic databases search yielded 133 articles (• Fig. 1). 6 articles that investigated the relation between patellar tendinopathy and jumping biomechanics were included in

	Pubmed	Amed	Embase
Studies identified	70	24	39
Total studies identified	133		
After checking for duplicates	102		
After excluding reviews/letters/abstracts	90		
After reading articles	6		
After reference checking	6		

Fig. 1 Literature search.

the review [2,6,23,24,26,27]. The data required to calculate effect sizes could not be obtained from 2 studies, which were therefore excluded from the quantitative analysis [23,24].

Description of the studies

Characteristics of the included studies are given in • Table 1. 4 studies compared subjects with clinically diagnosed symptomatic PT to a control group [23,24,26]. The study by Bisseling et al. (2008) compared a group of controls to an asymptomatic group with previous PT [2]. Edwards et al. included subjects without present or previous symptoms, but with patellar tendon ultrasonographic abnormality (PTA), and compared them to subjects without ultrasonographic abnormalities [6]. Because the presence of PTA increases the likelihood of the onset of PT [9,13,15], studying a group with PTA provides the opportunity to study subjects without symptoms but with a high risk for developing PT.

Jump tasks that were investigated were a volleyball spike jump [2,23,24,27], the volleyball block jump [24], a running layup jump and a countermovement jump [26], and a stop jump task [6]. From the study of Siegmund et al. (2008) only the running layup jump was included, because the described countermovement jump was not considered to be sport-specific. 4 of the 6 studies biomechanically examined both take-off and landing [2,23,24,26], one analysed the landing only [6] and one study examined the take-off only [27]. The study of Edwards et al. (2010) analysed both the horizontal landing component of a jump with forward acceleration and the vertical landing component of a vertical jump that immediately followed the horizontal jump [6].

Methodological quality assessment

No prospective studies were found during the search, and all studies included had a cross-sectional design. The methodological quality scores of the studies are shown in • Table 2. Quality scores ranged between 69% and 85%. None of the studies indicated gave a clear description of the population from which their participants were recruited (quality assessment items 11 and 12).

Table 1 Characteristics of included studies.

Author (year)	Factors	Analysed jump phase	Jump action	Population	N	Groups (N)
Richards et al. (1996)	kinematics and kinetics (knee)	TL	block jump and spike jump	men of the Canadian National volleyball team	10	control (7) with symptomatic PT (3)
Richards et al. (2002)	kinematics and kinetics (ankle)	TL	spike jump	men of the Canadian National volleyball team	10	control (7) symptomatic PT (3)
Bisseling et al. (2008)	kinematics, kinetics and energetics (knee, ankle)	TL	spike jump	male elite volleyball players	15	control (8) previous PT (asymptomatic) (7)
Siegmund et al. (2008)	kinematics (hip, knee, ankle)	TL	standing counter-movement jumps, running layup jumps	male basketball players, elite and recreational	24	control (12) symptomatic PT (12)
Edwards et al. (2010)	kinematics, kinetics and EMG (hip, knee, ankle)	L	stop jump	male athletes from team sports involving repetitive landing	14	controls (7) PTA, no previous or current symptoms (7)
Sorenson et al. (2010)	kinematics, kinetics and energetics (knee)	T	spike jump	male elite volleyball players	13	controls (7) PT without self-reported activity limitations (6)

Table 2 Methodological quality assessment of the included studies.

	Richards et al. 1996	Richards et al. 2002	Bisseling et al. 2008	Siegmund et al. 2008	Edwards et al. 2010	Sorenson et al. 2010
1. clear objective	0	1		1	1	1
2. clear description of main outcomes	1	1	1	1	1	1
3. clear description of patient/subject characteristics	1	1	1	1	1	1
4. clear description of intervention	1	1	1	1	1	1
6. clear description of main findings	1	1	1	1	1	1
7. estimates of random variability described	0	0	1	1	1	1
10. reporting of actual probability values	1	1	1	1	1	1
11. subjects examined representative of entire population	0	0	0	0	0	0
12. included subjects representative of entire population	0	0	0	0	0	0
16. planned analysis	1	1	1	1	1	1
18. statistical analysis appropriate	1	1	1	1	1	1
20. accuracy of outcome measures	1	1	1	1	1	1
25. adjustment for confounding	1	1	0	1	1	0
quality index score (out of 13)	9	10	10	11	11	10
quality index %	69%	77%	77%	85%	85%	77%

Differences in kinematics between groups

The effect sizes of all reported kinematic variables are separately presented for take-off (● Fig. 2), vertical landing (● Fig. 3, 4) and horizontal landing (● Fig. 5, 6). Differences between groups were found for a number of kinematic variables.

Subjects with PT vs. controls

The quantitative analysis of the studies showed no differences in kinematics between subjects with patellar tendinopathy and controls (● Fig. 2–4). Some variables showed a trend towards a difference. Subjects with patellar tendinopathy showed smaller maximum dorsiflexion angles for the ankle and a lower maximum angular acceleration for the hip both during landing and lower peak and average knee angular velocity for the eccentric phase during takeoff [26,27]. From the studies for which no data could be obtained to calculate effect sizes, a larger maximal knee flexion angle (in subject with PT) during landing from a spike jump was the only variable for which a difference between groups was found [24].

Subjects with previous PT vs. controls

There were no differences between subjects who had PT in the past and controls (● Fig. 2–4). A trend towards a difference was

found for some variables. Subjects with previous PT showed smaller knee flexion at time of peak VGRF, a smaller knee ROM from initial contact to peak VGRF and a larger eccentric angular velocity of the knee, all during landing [2]. Furthermore, subjects with previous PT showed a smaller plantar flexion angle at initial contact [2].

Subjects with PTA vs. controls

There were a number of differences between subjects with PTA and controls. Most differences were found for the horizontal landing phase (● Fig. 5, 6). At initial contact of horizontal landing, subjects with PTA showed more hip flexion, a higher hip extension velocity, more knee flexion and a higher knee extension velocity than controls [6]. At time of peak VGRF of horizontal landing subjects with PTA showed an opposite direction of hip velocity compared to controls, hip abduction as opposed to adduction and knee internal rotation instead of external rotation [6]. At time of peak PTF, subjects with PTA showed a higher knee angular velocity, more hip adduction and higher hip external rotation velocity [6].

There were also some differences between subjects with PTA and controls during the vertical landing (● Fig. 3, 4). Subjects with PTA showed more hip internal rotation velocity at initial

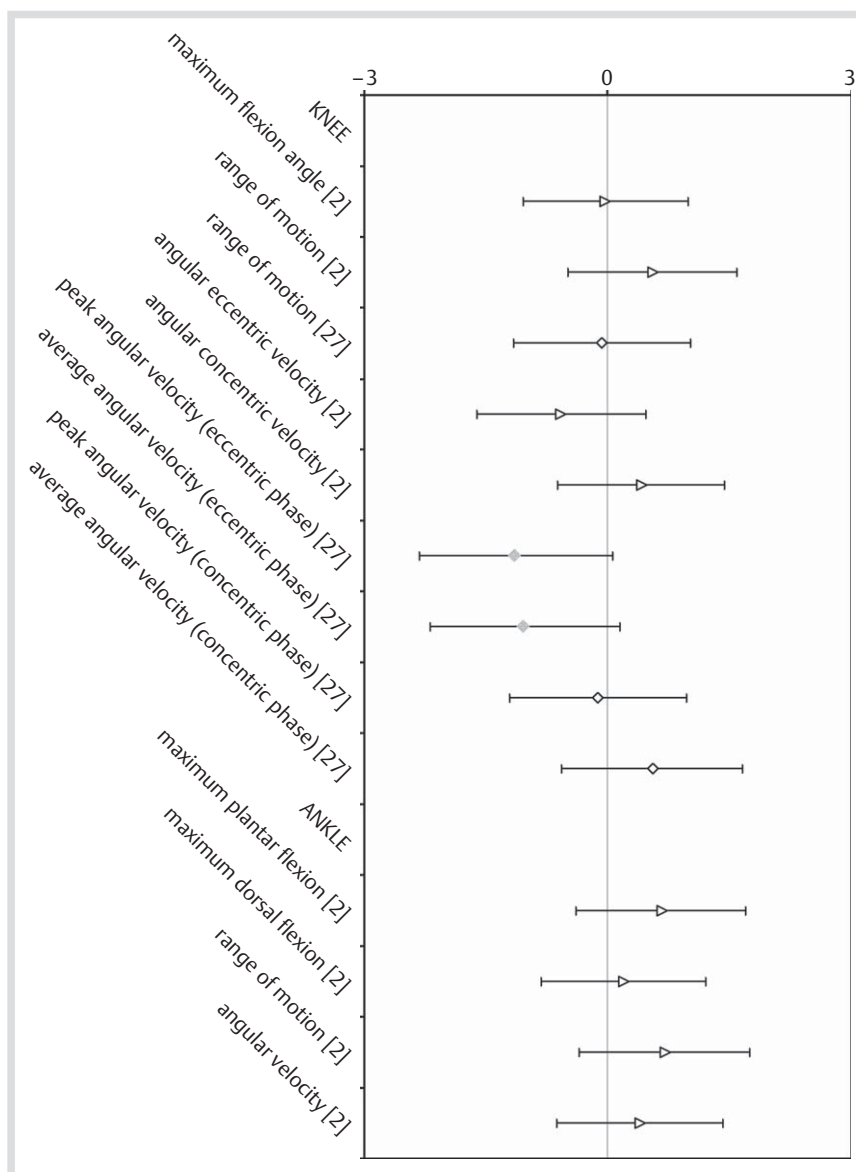


Fig. 2 Differences in take-off kinematics between controls and cases for knee and ankle (a positive value reflects a greater value in cases compared to controls. \blacktriangleright = subjects with previous PT, \blacklozenge = subjects with symptomatic PT. White symbols = non-significant effect, grey symbol = zero is outside 90% confidence interval).

contact and more ankle inversion at time of peak PTF than controls [6].

There was a trend towards a difference between groups during horizontal landing for hip abduction velocity, knee internal rotation (at initial contact), hip flexion, knee flexion, hip internal rotation (at time peak VGRF), knee flexion, hip abduction velocity and forefoot abduction velocity (at time peak PTF). During horizontal landing, there was a trend towards a difference for hip angular velocity, ankle flexion and ankle inversion (all at time of peak VGRF) [6].

Discussion

The aim of this systematic review was to achieve a better understanding of how PT may be related to take-off and landing kinematics. 6 studies were identified that met the inclusion criteria. From 4 of these studies the data could be entered in the quantitative analysis. The review only found differences in kinematics between subjects with PTA and controls. Because PTA is thought to be a precursor of PT, the main finding of the present review is that the risk for PT is greatest during landing and especially dur-

ing landing from a horizontal jump as the majority of the differences was found for (horizontal) landing. No differences were found for the take-off phase.

Because PTA is thought to be a precursor of symptomatic PT [9, 13, 15], subjects with PTA constitute a high risk population for developing PT and likely show jump biomechanics that are also risky. Thus, although no prospective studies are available in the literature, and it is therefore, strictly speaking, impossible to discern causes and effects, even for subjects with a high risk for PT such as subjects without current or previous symptoms but with PTA or (to a lesser extent) subjects with previous PT, it is possible to draw some hypotheses regarding causality.

During horizontal landing, subjects with PTA showed higher angular velocities and a less upright position at initial contact (more hip and knee flexion). The larger initial knee flexion angles at touchdown limited the available range of motion during landing, which is associated with decreased displacement of the center of mass after touchdown and, thereby, increased "stiffness" of the landing [4]. Increased landing stiffness entails increased loading rates and peak forces to the patellar tendon. These subjects also showed more hip abduction and more internal knee rotation [6]. The combination of hip abduction and

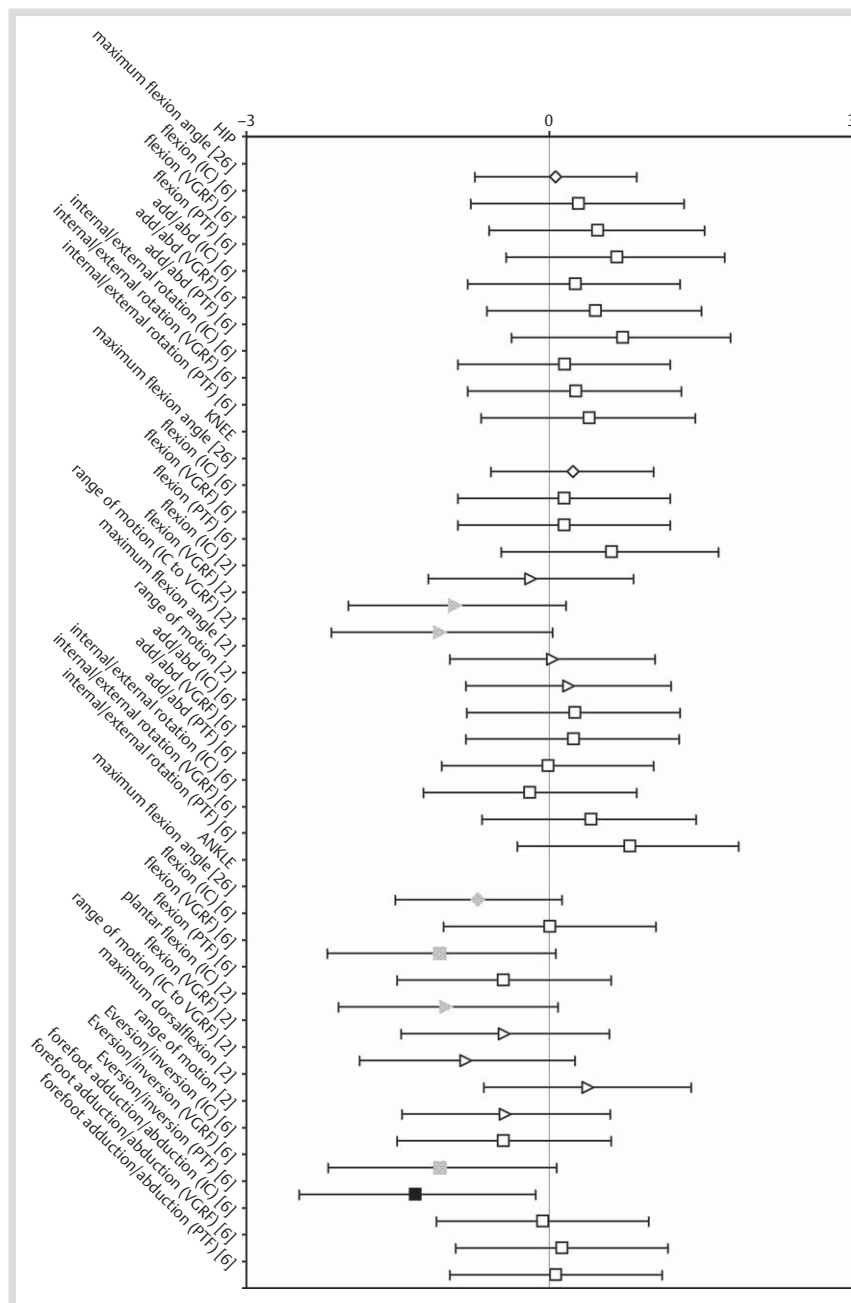


Fig. 3 Differences in vertical landing position kinematics between controls and cases for hip, knee and ankle (a positive value reflects a greater value in cases compared to controls. ■ = subjects with PTA, ▴ = subjects with previous PT, ♦ = subjects with symptomatic PT. White symbols = non-significant effect, grey symbol = zero is outside 90 % confidence interval, black symbol = zero is outside 95 % confidence interval). IC = at time of initial contact; VGRF = at time of maximal vertical ground reaction force; PTF = at time of maximal patellar tendon force; add = adduction; abd = abduction.

internal knee rotation leads to an increased load on the medial part of the patellar tendon, which is in line with the observation that pathology is present in the medial part of the patellar tendon in subjects with patellar tendinopathy [34]. The quantitative analysis revealed some differences in kinematics for the vertical landing, but only for subjects with PTA, just as for the horizontal landing. Higher hip internal rotation was seen at initial contact and more ankle inversion later on in the landing phase for subjects with PTA compared to controls [6]. These differences can also be explained by an increased load on the medial side of the patellar tendon.

No differences were found for subjects with symptomatic PT and subjects with previous PT compared to controls. When a less strict criterion was used (90% CI) some differences were found between groups (grey symbols • Fig. 2–6). Based on the kinematics of subjects with symptomatic PT it can be hypothesized that they used a tendon-load-avoiding movement pattern to

minimize pain, a pattern that is characterized by lower angular velocities and accelerations and greater range of motion. Subjects with previous PT showed a style similar to the PTA group with high angular velocities and knee and ankle flexion angles at touchdown that reduce the available range of motion. An explanation may be that the group with previous PT is, just like subjects with PTA, a high-risk population and therefore also exhibited risky jump biomechanics.

While no differences between any of the groups were found for the take-off phase, there was a trend towards significance for knee angular velocity during the eccentric (countermovement) phase of take-off in subjects with PT [27]. This highlights the relation between fast eccentric breaking forces and PT, as all variables showing a significant difference or a trend towards a significant difference are related to eccentric movement. According to one of the main pathophysiological theories on tendinopathy, microtrauma in the tendon resulting from repeated

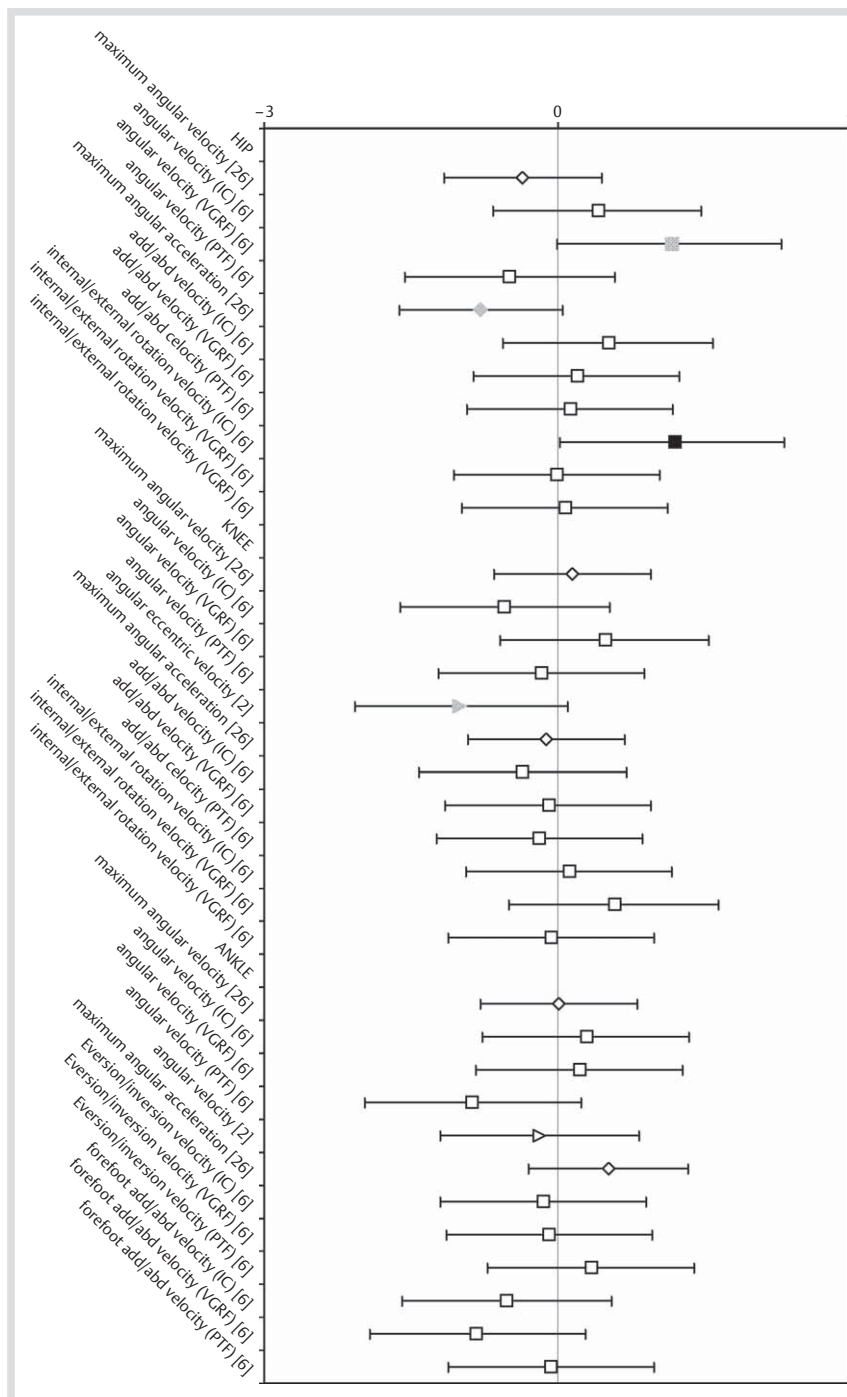


Fig. 4 Differences in vertical landing velocity/acceleration kinematics between controls and cases for hip knee and ankle (a positive value reflects a greater value in cases compared to controls. ■ = subjects with PTA, ▴ = subjects with previous PT, ♦ = subjects with symptomatic PT. White symbols = non-significant effect, grey symbol = zero is outside 90 % confidence interval, black symbol = zero is outside 95 % confidence interval). IC = at time of initial contact; VGRF = at time of maximal vertical ground reaction force; PTF = at time of maximal patellar tendon force; add = adduction; abd = abduction.

overload can eventually lead to matrix and cell changes as well as altered mechanical properties of the tendon [22]. Eccentric loads especially are thought to produce microtrauma due to being much greater than concentric loads [16]. Contrasting this idea, a study that measured peak knee moments generated by the patellar tendon with an implanted fibre optic sensor during (concentric) take-off and (eccentric) landing of a maximal vertical jump found no differences in peak moments between the 2 phases in healthy subjects [7]. However, the present review indicates that differences between groups were found only for the landing phase and not for the take-off phase, which suggests that subjects who are not able to cope with these peak eccentric patellar tendon torques during landing may be more prone to developing PT. When landing is concerned, there is a difference

between landing from a vertical jump, where only vertical deceleration has to be achieved, and landing from a forward jump, where horizontal deceleration also has to be achieved. A study that compared the horizontal landing phase (after forward acceleration) and the vertical landing phase during a stop-jump task found that the control group and PTA group differed more during the horizontal landing phase [6]. Taken with the finding that the peak force in the patellar tendon is higher during landing from a jump that has a horizontal component compared to landing from a jump that only has a vertical component [5], this would suggest that the horizontal component may play an important role in the onset of PT. This may also explain why the prevalence of PT is highest in volleyball players [17, 35], because, although similar movements are performed in basketball and

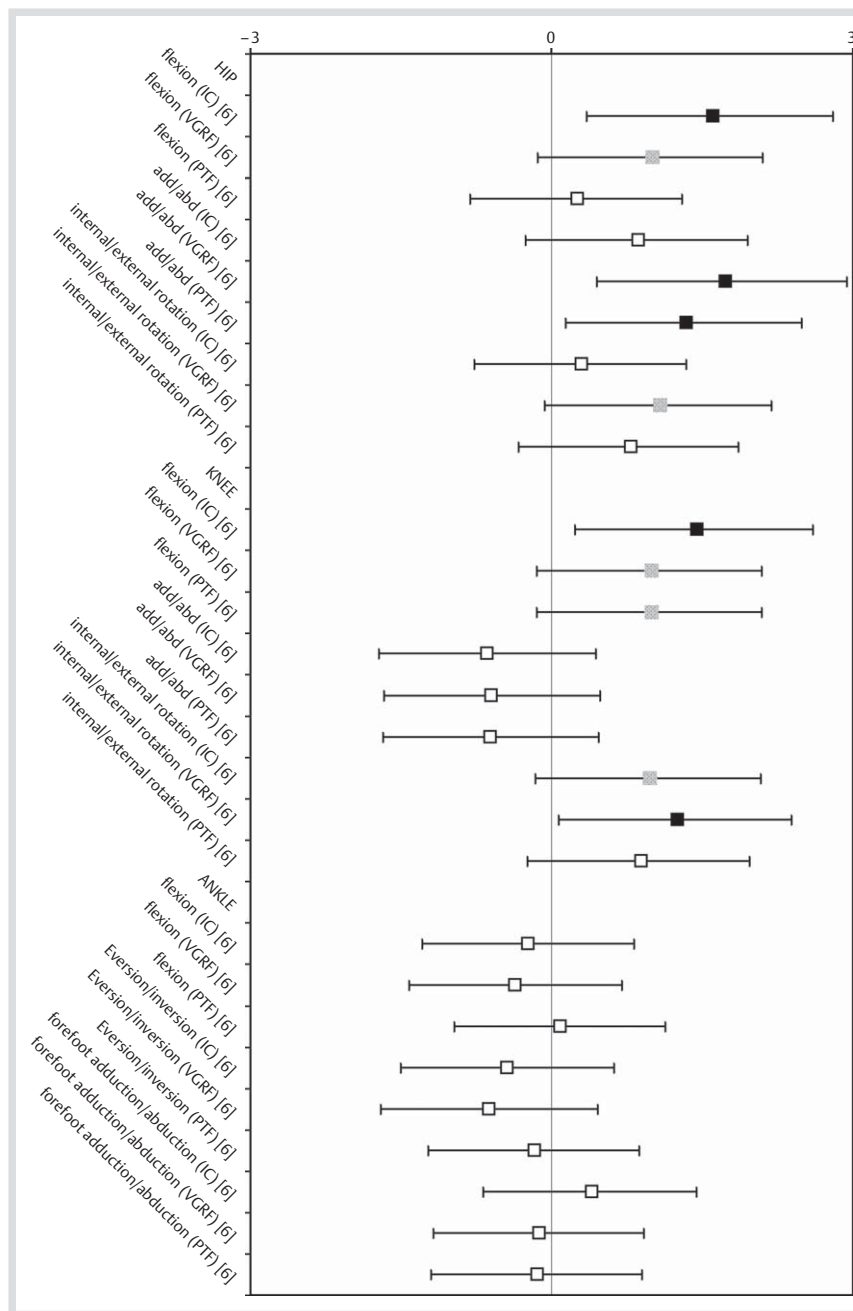


Fig. 5 Differences in horizontal landing position kinematics between controls and cases for hip, knee and ankle (a positive value reflects a greater value in cases compared to controls. ■ = subjects with PTA, ▒ = subjects with previous PT, ◆ = subjects with symptomatic PT. White symbols = non-significant effect, grey symbol = zero is outside 90 % confidence interval, black symbol = zero is outside 95 % confidence interval). IC = at time of initial contact; VGRF = at time of maximal vertical ground reaction force; PTF = at time of maximal patellar tendon force; add = adduction; abd = abduction.

soccer, for example, the net in volleyball forces players to reduce the forward horizontal velocity to zero during the landing after a spike jump, leading to high loads exerted on the patellar tendon. Another explanation may be that due to the net the volleyball player has no possibility to move the upper body forward (by flexing the hip) to achieve deceleration, which increases the load on the lower extremities.

The methodological quality of the included studies was good, with very little difference between studies, despite no prospective studies being found. The only study that found significant differences between groups had the highest methodological quality score [6]. 2 studies conducted by the same authors and on the same subjects could not be included in the quantitative analysis, since the required data was not included in the article and could not be obtained from the authors. However, the results from these studies would not have changed the findings of the present review as the results of this study are in line with the

idea that subjects with symptomatic PT used a load-avoiding strategy. The results of the 4 remaining studies were difficult to cluster because they differed in the adopted research methods, the time interval/moment to which the presented variables relate and the jump actions that were studied. A limitation is that all significant findings originated from the same study, namely the study by Edwards et al. (2010) [6]. This should be taken into account when interpreting the results of the present review.

The present review suggests that risk factors for developing PT are in general 1) joint flexion angles at touchdown that reduce the available ROM, 2) small post-touchdown ROM in the joints and 3) high post-touchdown joint angular velocities. Furthermore, landing technique appears to pose a greater threat for developing PT compared to take-off technique, and this threat is especially high during horizontal landing after a forward acceleration. This may be relevant for prevention of this injury, since

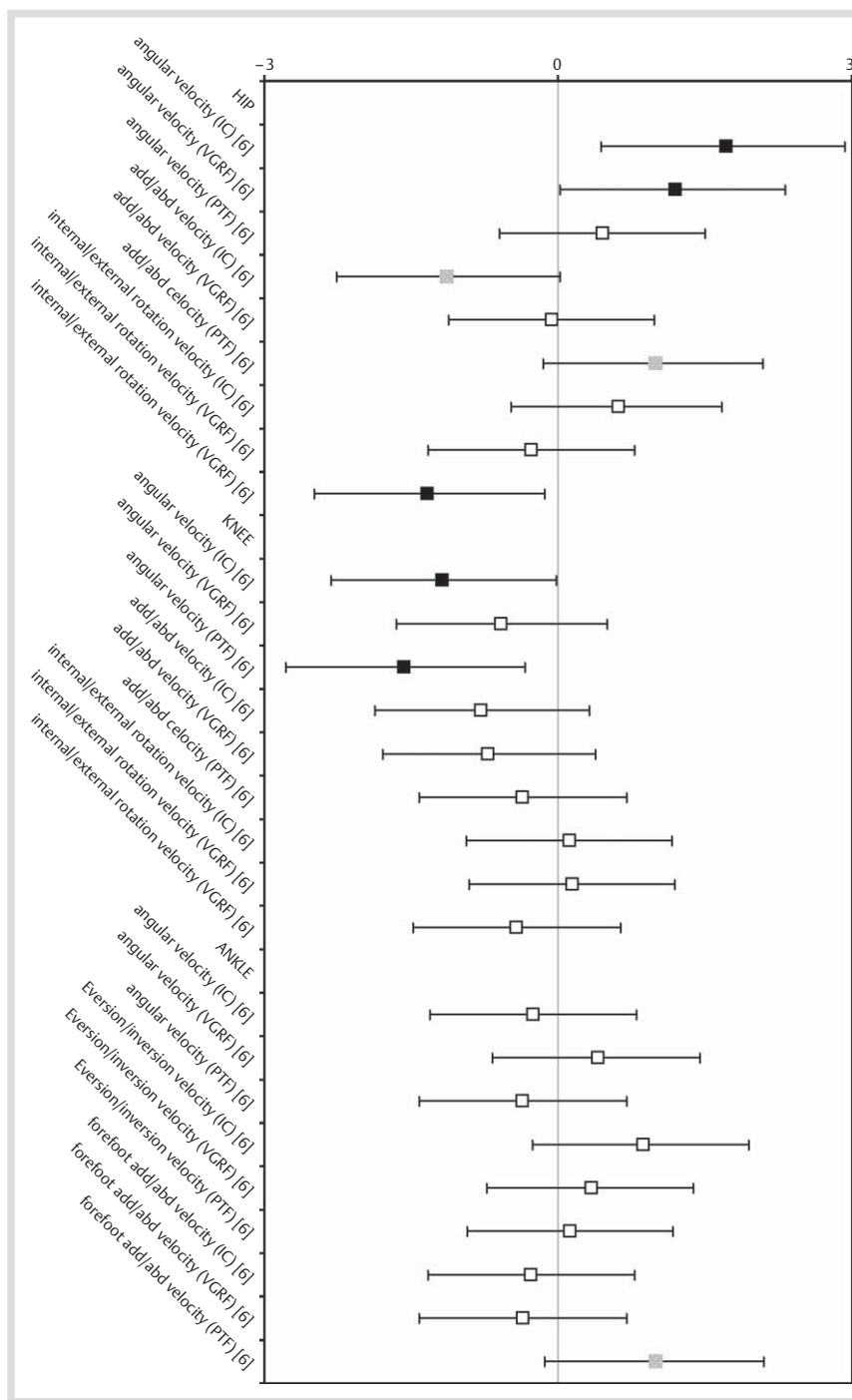


Fig. 6 Differences in horizontal landing velocity/acceleration kinematics between controls and cases for hip knee and ankle (a positive value reflects a greater value in cases compared to controls. ■ = subjects with PTA, ▴ = subjects with previous PT, ♦ = subjects with symptomatic PT. white symbols = non-significant effect, grey symbol = zero is outside 90 % confidence interval, black symbol = zero is outside 95 % confidence interval). IC = at time of initial contact; VGRF = at time of maximal vertical ground reaction force; PTF = at time of maximal patellar tendon force; add = adduction; abd = abduction.

it suggests that employing a more flexible jumping pattern, with a large post-touchdown ROM and landing time, may reduce the risk of developing PT. This may be achieved in 2 ways. First, it has been shown in a number of clinical studies that reduced flexibility of the kinetic chain, such as reduced flexibility of the upper leg muscles and reduced dorsiflexion range [1, 18, 32], are related to tendinopathy. Therefore, optimizing kinetic chain function (by addressing strength, flexibility and joint function), which is one of the main elements of a patellar tendon rehabilitation program according to Kountouris and Cook (2007) [14], may also be valuable for preventing patellar tendinopathy. Second, changing stiff landing patterns, with small post-touchdown ROM and short landing time, in favour of more flexible patterns is another option for prevention. Indeed, it has been shown that it is pos-

sible to modify jump technique by verbal instruction or videotape feedback [19,21]. Before applying such interventions, obviously "risky" take-off and landing patterns will have to be detected first. Therefore, a first step may be to investigate whether experts such as trainers and coaches are able to visually recognize "risky" landing techniques or whether they can be trained to recognize these techniques. In view of these findings, prevention strategies should focus on kinetic chain function and on changing stiff landing patterns.

Furthermore, the current notion that PT relates to landing technique (involving eccentric loading) more so than the jump take-off (involving primarily concentric loading) supports the idea of using eccentric training in the rehabilitation of PT [14]. While single leg decline squats are often used for this purpose [31],

inertial resistance training may also be considered as it more closely mimics the fast eccentric forces during landing [25]. Adapting the tendon to these fast eccentric forces may reduce the detrimental effect thereof. Eccentric exercises may therefore also be investigated for their potential use as a preventive measure in addition to their rehabilitative function [9].

Finally, future research focusing on risk factors for PT should preferably use a prospective design to improve on the current cross-sectional studies. This will enable us to gain more insight into the causality of the relation between jump kinematics and injury. Furthermore, though the subject of study is labelled a knee problem, joints are obviously connected. This is not reflected in the literature, where joints are often studied separately. Thus, in line with the kinetic chain function approach in PT rehabilitation [14], studying the coordination between joints (see e.g., Hughes et al. (2008), Yeow et al. (2011)) [11,33] may provide valuable information about jumping patterns in relation to developing and accordingly preventing PT.

Conclusion

Although the identified studies were diverse in methods that were used, the jump actions that were studied and in the reporting of variables, a synthesis of the literature suggests that PT is associated with factors related to horizontal landing more so than take-off, which may raise the question whether a more appropriate label for this injury might be “lander’s knee” rather than “jumper’s knee”. Furthermore, employing a flexible landing pattern may be an expedient way to reduce the risk for PT in athletes that take part in sports that involve jump actions. We propose investigating kinetic chain functioning, eccentric training and, in particular, changing landing patterns as possible preventive interventions.

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